IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: SARDA, Sylvain

Serial No: 09/455, 408

Filed: December 6, 1999

For: METHOD FOR MODELLING FLUID FLOWS IN A FRACTURED MULTILAYER POROUS MEDIUM AND CORRELATIVE INTERACTIONS IN A PRODUCTION WELL

Group: 2123

Examiner: Jones, H.

DECLARATION OF BERNARD BOURBIAUX PURSUANT TO 37 CFR §1.132

I, **Bernard Bourbiaux**, being duly warned, declare and say as follows:

THAT, I am a French Citizen holding an Engineering Degree, from Ecole Nationale Supérieure de Géologie (Applied Geology), Nancy, and a Mastère in Reservoir Management from Ecole Nationale du Pétrole et des Moteurs (ENSPM) (French Institute of Petroleum, IFP School);

residing in France at Rueil Malmaison (postal code: 92500), 23 Av. des Chateaupieds;

THAT, I have been engaged on researches relating to fractured reservoirs modelling and simulation by the Institut Français du Pétrole, since 1995;

THAT, I am familiar with the method described in the above-referenced patent application ; which method relates to modelling of fluid flows in a fractured multilayer porous medium and correlative interactions in a production well; and

THAT, the specification of the cited Patent Application is adequate and does enable one of ordinary skill in the art to carry out all the steps of the described method as defined in the claims.

I think particularly that the way to calculate the volume of fracture meshes is adequately disclosed in the specification, as explained hereafter.

Volume of Fracture Meshes

The specification (paragraphs [0020] - [0027]) sets forth with suitable emphasis being added:

[0020] The method comprises meshing the multilayer fractured reservoir modelled for example by means of the fractured reservoir modelling technique described notably in the aforementioned FR patent 2,757,947, assuming that the fractures are substantially perpendicular to the layer boundaries.

[0021] In order to form this mesh pattern, all the fracture intersections or computing nodes are located (Fig. 1) and fracture meshes are formed by associating a single matrix block MB (Fig. 2) with each node. For the purpose of 3D modelling, additional nodes have to be added in the neighboring layers in order to account for the fractures that run across several layers. The computed nodes thus defined constitute the center of the fracture meshes. The meshes are given boundaries such as the ends of the fractures on the one hand and the midpoint of the segments connecting the computing nodes on the other hand. Considering these boundaries imposed on the meshes, the volume ϕ of the meshes can be calculated (See relation 1). Calculation of the connections between fracture meshes (transmissivities) used for calculation of the inter-mesh flows can be carried out according to the method described in the aforementioned FR patent 2,757,947.

1) Matrix medium discretization

[0022] Discretization of the matrix medium assigns a rock volume to each fracture mesh. During dynamic simulation, exchanges between the matrix and the fractures are calculated in the pseudosteady state (exchange flow proportional to the pressure difference) between each fracture mesh and the associated single matrix block.

[0023] For calculation of the matrix volumes, the problem is dealt with layer by layer, which amounts to disregarding the vertical flows in relation to the horizontal flows in the matrix.

[0024] <u>For a given layer, the blocks are defined as follows</u>:

- <u>the block heights are equal and fixed to the height of the layer</u>,

- <u>in the plane of the layer, the surface area of the block associated with a fracture mesh is all the points that are closer to the fracture mesh than to another one</u>.

[0025] Physically, this definition implies that the boundaries at zero flow in the matrix are the equidistance lines between the fracture meshes. This approximation is valid if the neighboring fractures are at very close pressures, which is true in the presence of highly conducting fractures in relation to the matrix.

a) Block geometry

[0026] <u>In order to determine the geometry of the blocks in a given layer, a two-dimensional problem has to solved which finds, for each fracture mesh, the points that are closer to this mesh than to another one. This problem is solved by using for example, but preferably, the geometric method described in the other aforementioned FR patent 2,757,957, which allows, by discretizing the fractured layer into a set of pixels and by applying an image processing algorithm, to determine the distance from each pixel to the closest fracture</u>. During the initialization phase of this algorithm, value 0 (zero distance) is assigned to the pixels belonging to a fracture and a high value is assigned to the others. Furthermore, if the number of the fracture mesh to which each fracture pixel belongs is given in this phase, the same algorithm finally allows to determine, for each pixel:

- the distance from this pixel to the closest fracture mesh,

- the number of the closest fracture mesh.

[0027] <u>All of the pixels having the same fracture mesh number constitute the surface area of the matrix block associated with this mesh. Multiplying this surface area by the height of the layer allows obtaining the volume of the block associated with the mesh. Fig. 2 shows an example of a thus obtained 2D matrix block</u>.

Paragraph [0027] summarizes the calculation of the volume of a matrix block as defined in accordance with the teachings in the present application and in FR 2,757,957 as the area of the "Matrix Block" of Fig. 2 times height which is simple

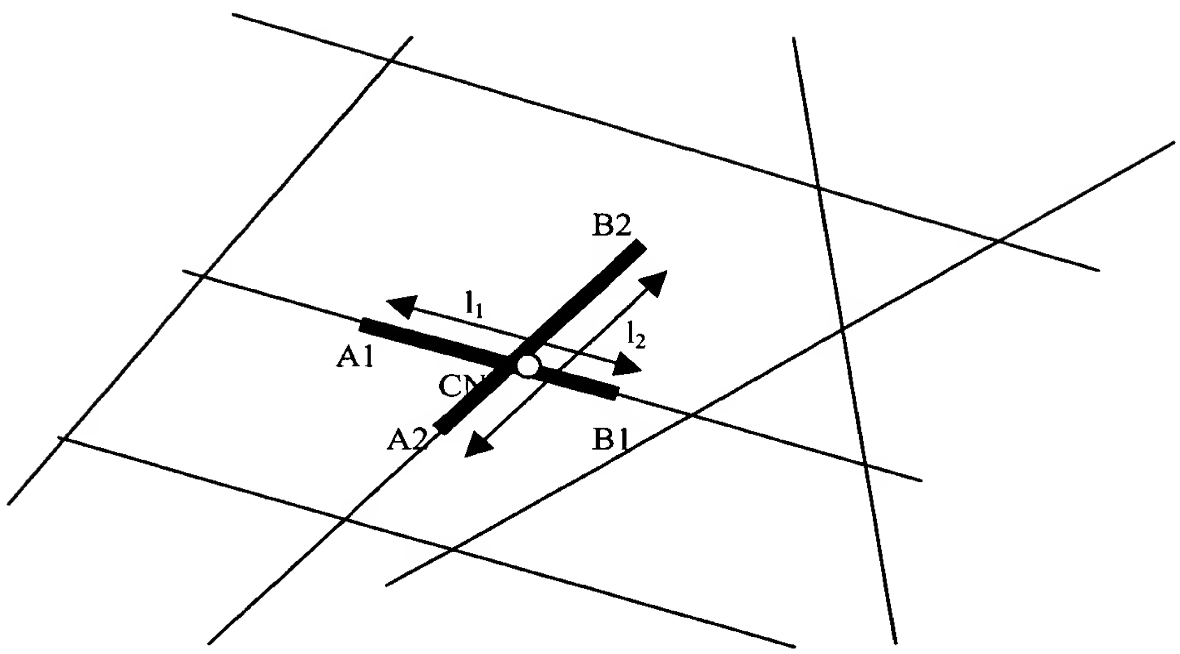
volumetric calculation of area times height as understood by persons of ordinary skill working in the field of the present invention.

Moreover in the cited prior FR patent 2,757,947:

Fig. 2 and Fig. 3 show the basic principle for dividing the fractures of a natural fracture network model into rectangles limited by layer interfaces; also shown in Figs. 5-9 the fractures are modelled as rectangles with a height h (thickness of a layer) and a length l.

Fig. 5 (and subsidiarily Figs. 6-9) shows the first step of the method of the invention used to discretize the fracture network, which places fracture nodes at the intersections of fracture planes within each layer, plus additional nodes to discretize fracture planes in other layers where no intersection with other fractures is observed.

Fig. 1 of the present patent application also shows the second step of fracture network discretization, which defines the limits of the Fracture Mesh (FM) corresponding to a given fracture node (also referred to as Computing Node (CN)) within a given geological layer: the Fracture Mesh consists in the two fracture segments crossing at the considered fracture node and limited either by the end of the fracture within the layer or by the midpoint between the considered node and the neighbouring node. The upper and lower limits of the fracture mesh are the interfaces between geological layers (consistently with Fig. 2 of FR patent 2,757,947);



The drawing above, which is a reproduction of Fig. 1 of the present application without the legends "Fracture Mesh" and "Computing Node", shows:

(i) O: CN = computing node

(ii) **Fracture Mesh (FM)** trace (in geological layer where it is defined) = segment [A1B1] + segment [A2B2]

- The dimensions of the fracture mesh defined as before from the geological network model are then used to compute fracture mesh volume. If h is the thickness of the geological layer containing the considered fracture mesh, and l_1 and l_2 are the respective lengths of the two constitutive fracture segments A1B1 and A2B2, and a_1 and a_2 their respective apertures, then the fracture mesh volume is very close to:

$$(a_1l_1 + a_2l_2)h$$

taking into account the fact that the area of intersection of the two fractures, which should actually be subtracted, is negligible because fracture apertures, a_1 and a_2, are several orders of magnitude lower than their lengths, l_1 and l_2.

This relationship is a simple example of what is taught in the above reproduced paragraphs [0020] - [0027] of the present application.

So the form of the fracture meshes being defined as well as the dimensions and limits thereof, I think it is clear for those of ordinary skill in the art to determine the respective volumes of the fracture meshes.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

28 July 2004

Date

Bernard Bourbiaux